PATENT ABSTRACTS OF JAPAN

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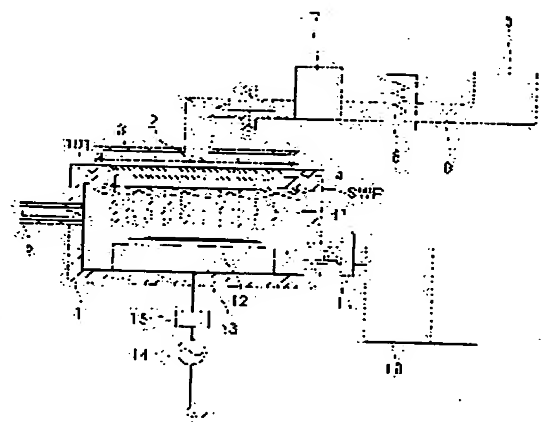
(54) DEVICE AND METHOD FOR MICROWAVE PLASMA TREATMENT

(57)Abstract:
PROBLEM TO BE SOLVED: To provide a device and method for microwave plasma treatment by which the uniformity of plasma can be secured on the surface of a substrate by preventing the occurrence of a standing wave near the surface of a dielectric window without performing any complicated processing on the dielectric window.



SOLUTION: The dielectric window for transmitting microwave is constituted so that the surface of the window facing the substrate may be positioned at the same position as that of the internal wall surface of the ceiling section of a plasma treatment vessel or in a state where the surface is protruded to the substrate side than the position of the internal wall surface of the ceiling section. In addition, the distance between the outer peripheral section of the dielectric window and the side wall surface of the plasma treatment vessel is adjusted to at least the 1/4 of the wavelength of an introduced microwave or longer. Consequently, the uniformity of the plasma can be secured on the surface of the substrate even when no complicated processing is performed on the dielectric window.

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CLAIMS

[Claim(s)]
[Claim 1]
The head-lining section is equipped with the plasma treatment container by which opening was carried out, and the dielectric window for microwave transparency airtightly prepared in this head-lining section at least. In the microwave plasma treatment equipment constituted so that the above-mentioned dielectric window may be countered and a substrate can be installed in a plasma treatment container the location as the location of the head-lining section internal surface of a plasma treatment container where the front face of the above-mentioned dielectric window which countered the substrate is the same -- or the microwave plasma treatment equipment characterized by being constituted so that it may be projected and located in a substrate side rather than the location of this head-lining section internal surface.
[Claim 2]
Microwave plasma treatment equipment according to claim 1 characterized by constituting the front face of the above-mentioned dielectric window which countered the substrate so that it may be projected and located in at least 5mm substrate side from the location of the head-lining section internal surface of a plasma treatment container.
[Claim 3]
the location as the location of the head-lining section internal surface of a plasma-treatment container where the front face of the inside surrounded by this lobe be the same when a ring-like lobe be prepare in the outside edge of the front face of the above-mentioned dielectric window which countered the substrate -- or claim 1 characterize by to be constitute so that it may be project and locate in a substrate side rather than the location of this head-lining section internal surface or microwave plasma-treatment equipment according to claim 2.
[Claim 4]
Microwave plasma treatment equipment the claim 1 publication characterized by the distance between the periphery section of the above-mentioned dielectric window and the side-attachment-wall side of a plasma treatment container being separated more than the quadrant of the wavelength of the microwave to introduce thru/or given in either of claims 3.
[Claim 5]
Microwave plasma treatment equipment according to claim 4 characterized by the distance between the periphery section of the above-mentioned dielectric window and the side-attachment-wall side of a plasma treatment container being 30mm or more when the frequency of the microwave to introduce is 2.45GHz.
[Claim 6]
Microwave plasma treatment equipment according to claim 1 to 5 with which the path of the above-mentioned dielectric window is characterized by being twice [more than] the path of a substrate.
[Claim 7]
It is microwave plasma treatment equipment according to claim 2 to 5 which makes a radius distance of the inside front face and substrate which were surrounded by this lobe, and is characterized by setting the path of a dielectric window that this lobe is not contained in each

circle centering on substrate both ends when a dielectric window prepares a lobe according to claim 3.

[Claim 8]

The material gas for exciting the plasma with a gas supply means is supplied to a plasma treatment container. The microwave made to oscillate and amplify with a microwave generating means is made to introduce and irradiate an antenna means. This irradiated microwave is introduced into the above-mentioned plasma treatment container of a vacuum ambient atmosphere through the dielectric window for microwave transparency. In the art which carries out microwave plasma treatment of the substrate which generated the plasma, countered the above-mentioned dielectric window for microwave transparency, and was formed in the plasma treatment container by the electromagnetic field which this microwave builds The microwave plasma treatment approach characterized by performing plasma treatment using microwave plasma equipment according to claim 1 to 7.

[Translation done.]

* NOTICES *

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention]
This invention relates to the art which used microwave plasma treatment equipment and this equipment.
[0002]
[Description of the Prior Art]
In recent years, in the production process of a semiconductor device, plasma treatment equipment is used abundantly with detailed-izing of semiconductor devices, such as LSI. The homogeneity of the above-mentioned plasma treatment within a wafer side contributes greatly stability, a yield, etc. of a property of this semiconductor device. The homogeneity of this plasma treatment is secured by distributing the plasma over homogeneity on a wafer front face. Then, by keeping away the distance of the plasma production section of for example, plasma treatment equipment, and a substrate, the plasma is diffused and the device of making it homogeneity can be considered on a wafer front face.
[0003]
Recently, the microwave plasma treatment equipment which is stabilized also in the state of a high vacuum with a comparatively low pressure, and can excite the plasma attracts attention among plasma treatment equipment.
[0004]
About the plasma treatment using this microwave plasma treatment equipment, concretely, it direct-oxidizes, and a silicon front face is nitrided, and the case where the insulator layer of high quality is formed is explained as an example.
[0005]
When using microwave plasma treatment equipment, the above-mentioned insulator layer is formed within a metal plasma treatment container. In order to form opening in the head-lining section of this plasma treatment container and to introduce microwave in equipment, the dielectric window for microwave transparency which is made of the quartz etc. is airtightly prepared in this opening.
[0006]
On the occasion of formation of the above-mentioned insulator layer, if the distance of the front face by the side of the substrate of this dielectric window and a substrate is about 80mm or less, an antenna may adjust the exposure reinforcement of microwave so that the plasma generated may become homogeneity according to the type of gas and pressure which are used for the plasma treatment concerned.
[0007]
By the plasma being high-density at a part for a center section, or detaching the distance between the front face of a dielectric window, and a substrate 80mm or more, even if it is the case that homogeneity — a ring-like high density part is formed on the other hand — is bad, the plasma is spread and homogeneity is secured on a substrate front face.
[0008]

By the way, when the plasma is excited with microwave plasma treatment equipment, the wave of the microwave called a surface wave between the front face of a dielectric window and the generated plasma is formed. As for this surface wave, the plasma is formed in the dielectric window whole surface in breadth and the substrate upper part.
[0009]
Usually, since the location of the internal surface of the head-lining section of a plasma treatment container projects from the location of the front face of the above-mentioned dielectric window in the substrate side, the perimeter of this dielectric window is surrounded by the cross section of opening formed in the above-mentioned head-lining section. Therefore, if it reflects in the envelopment side where the above-mentioned surface wave consists of this opening cross section, a surface wave and this reflected wave will interfere mutually, and a standing wave will be formed near the front face of a dielectric window.
[0010]
This standing wave is the cause which checks the homogeneity of the plasma on the substrate front face in microwave plasma treatment. That is, the problem that the plasma consistency of the center section of the dielectric window turned into high density from the periphery of a dielectric window had arisen.
[0011]
Then, the configuration of an equipment wall surface where the periphery section of a dielectric window and a dielectric window are installed is made unevenness, and he negates a reflected wave, and was trying for a standing wave not to arise conventionally (for example, patent reference 1 reference.).
[0012]
[Patent reference 1]
JP,2002-190449,A (claim)
[0013]
[Problem(s) to be Solved by the Invention]
However, after it made it correspond to the plasma treatment in a certain specific type of gas and specific pressure and the antenna adjusted the exposure reinforcement of microwave, when plasma treatment was performed by a different type of gas or a different pressure, there was inconvenience that the homogeneity of the plasma worsened.
[0014]
Therefore, since when performing plasma treatment by two or more different types of gas or pressures, respectively had to adjust the exposure reinforcement of microwave each time, two or more plasma treatment from which a type of gas or a pressure differs by adjustment once was not completed, but there was [a problem that working efficiency fell].
[0015]
On the other hand, although the homogeneity on the front face of a substrate was securable when the distance between the front face of a dielectric window and a substrate was detached, the plasma consistency on the front face of a substrate fell simultaneously, the amount of attainment to the substrate of a labile kind decreased, and the problem that plasma treatment took time amount had arisen.
[0016]
Furthermore, although the above-mentioned inconvenience was canceled when making unevenness the configuration of the side attachment wall side of a plasma treatment container where the periphery section of a dielectric window and a dielectric window were installed in order to make it not produce the standing wave of the cause which checks the homogeneity of the plasma on the front face of a substrate, the processing technique make into an uneven configuration is complicated, and had substantially the problem that processing was difficult.
[0017]
Even if this invention does not perform complicated processing to the above-mentioned dielectric window in view of the above-mentioned trouble, it is made not to produce a standing wave near the front face of a dielectric window, and it makes it a technical problem to offer the microwave plasma treatment equipment and the art which can secure the homogeneity of the

plasma on the front face of a substrate.
[0018]
[Means for Solving the Problem]
In order to solve the above-mentioned technical problem, the microwave plasma treatment equipment concerning this invention The head-lining section is equipped with the plasma treatment container by which opening was carried out, and the dielectric window for microwave transparency airtightly prepared in this head-lining section at least. In the microwave plasma treatment equipment constituted so that the above-mentioned dielectric window may be countered and a substrate can be installed in a plasma treatment container the location as the location of the head-lining section internal surface of a plasma treatment container where the front face of the above-mentioned dielectric window which countered the substrate is the same — or it is characterized by being constituted so that it may be projected and located in a substrate side rather than the location of this head-lining section internal surface.
[0019]
Since there is no envelopment side which becomes the periphery section of a dielectric window from the cross section of opening formed in the head-lining section of a plasma treatment container according to this configuration, a surface wave does not reflect but formation of a standing wave can be controlled.
[0020]
Therefore, even if it changes conditions, such as a type of gas and a pressure, regardless of the distance of a dielectric window front face and a substrate, uniform plasma distribution can be acquired on a substrate front face.
[0021]
When the front face of the above-mentioned dielectric window which countered the substrate is located in a substrate side from the head-lining section internal surface of a plasma treatment container, as for the distance from this head-lining section internal surface to the front face of a dielectric window, it is desirable that it is at least 5mm.
[0022]
the location as the location of the head-lining section internal surface of a plasma treatment container where the front face of the inside surrounded by this lobe is the same when a ring-like lobe is prepared in the outside edge of the front face of the above-mentioned dielectric window which countered the substrate — or what is necessary is just to constitute so that it may be projected and located in a substrate side rather than the location of this head-lining section internal surface
[0023]
In addition, as for the distance between the periphery section of the above-mentioned dielectric window, and the side-attachment-wall side of a plasma treatment container, it is desirable that it is separated more than the quadrant of the wavelength of the microwave to introduce. This is for suppressing that microwave reflects in the direction of a center section of a dielectric window, and forms a standing wave by giving the tooth space in which the plasma is made to form between the periphery section of a dielectric window, and the side-attachment-wall side of a plasma treatment container.
[0024]
What is necessary is just to set distance of the periphery section of the above-mentioned dielectric window, and the side-attachment-wall side of a plasma treatment container to 30mm or more, when the frequency of the microwave which follows, for example, is introduced is 2.45GHz.
[0025]
Moreover, as for the path of the above-mentioned dielectric window, it is desirable that it is twice [more than] the path of a substrate. What is necessary is to make into a radius distance of the inside front face and substrate which were surrounded by this lobe, and just to set the path of a dielectric window that this lobe is not contained in each circle centering on substrate both ends, when preparing the above-mentioned lobe in the periphery section of a dielectric window furthermore. The die length of the path of a desirable dielectric window differs for not

affecting the thickness of a substrate edge by the lobe by the existence of this lobe.
[0026]
In order to solve the above-mentioned technical problem, moreover, the microwave plasma treatment approach concerning this invention The material gas for exciting the plasma with a gas supply means is supplied to a plasma treatment container. The microwave made to oscillate and amplify with a microwave generating means is made to introduce and irradiate an antenna means. This irradiated microwave is introduced into the above-mentioned plasma treatment container of a vacuum ambient atmosphere through the dielectric window for microwave transparency. In the art which carries out microwave plasma treatment of the substrate which generated the plasma, countered the above-mentioned dielectric window for microwave transparency, and was formed in the plasma treatment container by the electromagnetic field which this microwave builds It is characterized by performing plasma treatment to one of the above using the microwave plasma equipment of a publication.
[0027]
[Embodiment of the Invention]
Hereafter, the microwave plasma treatment equipment concerning the gestalt of operation of this invention is explained with reference to drawing 1 , drawing 2 , and drawing 3 .
[0028]
Drawing 1 is a sectional view showing the configuration of the microwave plasma treatment equipment for semi-conductor substrates as 1 operation gestalt of this invention. Drawing 3 and drawing 4 are the sectional views showing the conventional common microwave plasma treatment equipment for semi-conductor substrates.
[0029]
In drawing 1 , 1 is a metal plasma treatment container which performs plasma treatment. The coaxial waveguide converter and antenna 2 which adjust the exposure reinforcement of microwave are formed in the upper part of the head-lining section 101 of the plasma treatment container 1. The slot 3 which irradiates microwave is established between the coaxial waveguide converter and the antenna 2, and the dielectric window 4 airtightly prepared in opening of the head-lining section 101. In addition, the raw material of the above-mentioned dielectric window 4 is a quartz etc. This dielectric window 4 penetrates the microwave irradiated through the slot 3, and introduces microwave in the plasma treatment container 1.
[0030]
It oscillates by the magnetron 5 and this microwave (2.45GHz) is introduced into the above-mentioned coaxial waveguide converter and an antenna 2 through a waveguide 8.
[0031]
Inside the plasma treatment container 1, the above-mentioned derivative aperture 4 and the electrode 13 which holds the plasma treatment substrate 12 in the location which counters are, and a RF is impressed to this electrode 13 in it if needed from RF generator 14. In addition, the adjustment machine 15 performs impedance adjustment of this RF.
[0032]
Next, actuation of the microwave plasma treatment equipment in this operation gestalt is explained. From the side face of the plasma treatment container 1, the gas for exciting the plasma with the gas supply means 9 is supplied, the inside of the plasma treatment container 1 is made reduced pressure with a flue system 10, a pressure regulating valve 11 adjusts the process pressure of the plasma treatment container 1, and a raw material and reaction secondary generation gas are exhausted. The microwave oscillated and amplified by the magnetron 5 is introduced into a coaxial waveguide converter and an antenna 2 through the 4E tuner 7, and is irradiated from a slot 3. At this time, although a reflected wave is returned to the microwave processing container 1 side by the 4E tuner 7, it has prevented being absorbed with an isolator 6 about the reflected wave which cannot be adjusted, and returning to a magnetron 5. The microwave irradiated from the slot 3 is introduced inside the plasma treatment container 1 of a vacuum ambient atmosphere through a dielectric window 4, and forms Plasma P in the plasma treatment container 1 by the electromagnetic field which this microwave builds. This plasma P can perform etching, a membrane formation process, etc. In addition, SWP expresses typically

the front face of the derivative aperture 4, and the surface wave of the microwave produced between Plasma P.
[0033]
When performing oxidation treatment using the above-mentioned microwave plasma treatment equipment, rare gas and oxygen, such as an argon and a krypton, are mixed, more than total 0.17 Pa-m3/sec (100sccm) is introduced, and it processes in a 1-133Pa pressure range. the case where nitriding treatment is performed on the other hand -- for example, an argon, a krypton, etc. -- etc. -- rare gas, ammonia, nitrogen, and hydrogen are mixed, more than total 0.17 Pa-m3/sec (100sccm) is introduced, and it processes in a 1-133Pa pressure range.
[0034]
In drawing 1 , the location of the front face of the dielectric window 4 of the side which counters a substrate 12 projects in the substrate 12 side rather than the location of the internal surface of the head-lining section 101 of the microwave processing container 1. Therefore, that a surface wave SWP is irradiated by the metal side of the side attachment wall of the plasma treatment container 1 also forms an antinode and a knot in the periphery section of a dielectric window 4, without being reflected from a metal side. In addition, when it projects in a substrate 12 side and makes the front face of a dielectric window 4 located, the distance from the front face of a dielectric window 4 to the internal surface of the above-mentioned head-lining section 101 has about 5mm more desirable than the location of the internal surface of the above-mentioned head-lining section 101.
[0035]
In addition, what is necessary is to make into a radius r distance of the inside front face and substrate 12 which were surrounded by this lobe, and just to set the path of a dielectric window 4 that this lobe is not contained in each circle c centering on the both ends of a substrate 12 as drawing 2 shows when preparing a lobe in the periphery section of a dielectric window 4 like drawing 1 although it is desirable that it is twice [more than] the path of a substrate 12 as for the path of a dielectric window 4. The die length of the path of the desirable dielectric window 4 differs for not affecting the thickness of the edge of a substrate 4 by the lobe by the existence of this lobe. For example, the distance of the inside front face and substrate 12 which were surrounded by the lobe in drawing 1 is about 60mm, and when a substrate 4 is 200mm, the path of the inside surrounded by the lobe of a dielectric window 4 is set to about 280mm.
[0036]
Although the wave-like plasma may be formed depending on a pressure between the periphery section of a dielectric window 4, and the side-attachment-wall side of the plasma treatment container 1 at this time, in view of a substrate 12 side, this does not influence the plasma treatment of the front face of a substrate 12, but in order to consume power in the above-mentioned periphery section conversely, the plasma P of the front face of the dielectric window 4 on a substrate 12 becomes homogeneity. In this case, what is necessary is just to detach the distance between the periphery section of a dielectric window 4, and the side-attachment-wall side of the plasma treatment container 1 more than the quadrant of the wavelength of the microwave to introduce. For example, with the gestalt of this operation, since the microwave to introduce is 2.45GHz, it should just detach the distance of about 30mm or more so much in wavelength of 122mm.
[0037]
Although the coaxial waveguide converter and antenna 2 which are irradiated through a slot 3 are used as a means to introduce microwave in the microwave processing container 1, with the gestalt of this operation after changing microwave into the same axle, as an antenna means, otherwise, especially the thing that put in the slit can especially be used for a waveguide 8, and it is not limited to it.
[0038]
Drawing 3 shown for a comparison and the microwave plasma treatment equipment of a fundamental configuration of drawing 4 are the same as that of drawing 1 , and the same sign as drawing 1 shows the same configuration about the sign in drawing. In addition, the difference between the equipment of drawing 3 and the equipment of drawing 4 is the point that this lobe is

not prepared in the outside edge of the front face of a dielectric window 4 by drawing 3 to having prepared the ring-like lobe, in drawing 4 . Since drawing 3 and drawing 4 are in the location from a substrate 12 side where the location of the front face of a dielectric window 4 is more distant than the location of the internal surface of the head-lining section 101 in any case, the metal envelopment side which consists of an opening cross section formed in this head-lining section 101 is formed in the perimeter of a dielectric window 4. Although SWP' and SWP" are the surface waves expressed typically, since they short-circuit all in respect of [above-mentioned] metal envelopment, they generate a standing wave strong against a part for a center section. Consequently, a plasma consistency also becomes high in the part of the shape of a ring which encloses the center of a dielectric window 4, and the center of a dielectric window 4, and will spoil homogeneity.

[0039]

[Example]

The example of the plasma treatment hereafter performed using the microwave plasma treatment equipment concerning this invention is explained as compared with the case of conventional microwave plasma treatment equipment.

[0040]

Plasma oxidation processing and plasma nitriding treatment of the substrate 12 from which the natural oxidation film was removed were carried out to drawing 1 by rare 0.5% fluoric acid using the microwave plasma treatment equipment of drawing 3 , respectively.

[0041]

Plasma oxidation performed 80Pa and the processing time for the pressure as 10 minutes using Kr/O2 gas. On the other hand, plasma nitriding performed 8Pa and the processing time for the pressure as 7 minutes using Ar/NH3 gas. In the equipment of drawing 1 and drawing 3 , the distance of the front face of a dielectric window 4 and a substrate 12 was adjusted, and both were set to 60mm.

[0042]

thickness distribution of the oxide film in the location of the arbitration after plasma treatment and on a substrate and the nitride film — a spectrum — it measured by the distributed ellipsometer and the result was compared. The result of oxidation treatment is shown in drawing 5 , and the result of nitriding treatment is shown in drawing 6 , respectively.

[0043]

When plasma treatment is carried out using the microwave plasma treatment equipment concerning this invention, thickness distribution all shows good homogeneity. That is, each thickness is fixed near about 71A - 72A, when it oxidizes (drawing 5), and when nitriding treatment is carried out, it is fixed near about 46A - 50A (drawing 6). In addition, although not illustrated, also in different oxidation treatment and the nitriding treatment of conditions from the above, it was the same distribution inclination.

[0044]

On the other hand, when plasma treatment is carried out using the microwave plasma treatment equipment of drawing 3 , it turns out that the thickness of a substrate center section is all thick. That is, although it is about 80A in a substrate periphery when it oxidizes, it is about 103A in the substrate center section (drawing 5), and although it is about 33A in a substrate periphery when nitriding treatment of each thickness is carried out, it is about 59A in the substrate center section (drawing 6). The microwave reflected in respect of the envelopment of the above-mentioned metal which consists of an opening cross section formed in the head-lining section 101 forms a standing wave, and this is considered for the plasma consistency of the substrate center section of the dielectric window 4 to have gone up, as SWP' of drawing 3 showed.

[0045]

Furthermore, when it was 80Pa with a comparatively high pressure, the wave-like plasma was formed between the periphery section of the dielectric window 4 of the microwave plasma treatment equipment of drawing 1 , and the side-attachment-wall side of the plasma treatment container 1. Since this detached the distance between the periphery section of a dielectric window 4, and the side-attachment-wall side of the plasma treatment container 1 more than the

quadrant of the wavelength of the microwave to introduce With the conventional microwave plasma treatment equipment of drawing 3 To microwave reflecting in the center section of the dielectric window 4, in the case of the equipment of drawing 1 , the plasma is formed between the periphery section of a dielectric window 4, and the side-attachment-wall side of the plasma treatment container 1, and it thinks because it has prevented microwave reflecting in the center section of the dielectric window 4.

[0046]

[Effect of the Invention]

In the plasma treatment for which this invention used microwave so that clearly from the above explanation Or it constitutes so that it may be located in a substrate side rather than this head-lining section internal surface. the front face of the dielectric window which countered the substrate — the same location as the location of the head-lining section internal surface of a plasma treatment container — with the periphery section of a dielectric window further By detaching the distance between the side-attachment-wall sides of a plasma treatment container more than the quadrant of the wavelength of microwave, the standing wave which was the cause of reducing the homogeneity of the plasma until now can be controlled now. Therefore, even when the distance of the front face of a dielectric window and a substrate was near, even if it can secure the homogeneity of plasma treatment now and changed the type of gas and the pressure, it became possible to perform high processing of the homogeneity of the plasma, without adjusting the configuration of equipment each time.

[Brief Description of the Drawings]

[Drawing 1] The sectional view of the microwave plasma treatment equipment concerning this invention.

[Drawing 2] The sectional view showing the method of the decision of the path of the dielectric window at the time of preparing a lobe

[Drawing 3] The sectional view of conventional microwave plasma treatment equipment.

[Drawing 4] The sectional view of conventional microwave plasma treatment equipment (what prepared the ring-like lobe in the outside edge of the front face of a dielectric window).

[Drawing 5] Drawing showing the thickness distribution at the time of carrying out plasma oxidation processing of the silicon substrate using the equipment of drawing 1 and drawing 3

[Drawing 6] Drawing showing the thickness distribution at the time of carrying out plasma nitriding treatment of the silicon substrate to drawing 1 using the equipment of drawing 3

[Description of Notations]

1 Plasma Treatment Container
2 Coaxial Waveguide Converter and Antenna
3 Slot
4 Dielectric Window
5 Magnetron
6 Isolator
7 4E Tuner
8 Waveguide
9 Gas Supply Means
10 Exhaust Air Pump
11 Pressure Regulating Valve
12 Substrate
13 Electrode
14 RF Generator
15 Adjustment Machine
P Plasma
SWP surface wave

[Translation done.]

TECHNICAL FIELD

[Field of the Invention]
This invention relates to the art which used microwave plasma treatment equipment and this equipment.
[0002]

[Translation done.]

* NOTICES *

PRIOR ART

[Description of the Prior Art]
In recent years, in the production process of a semiconductor device, plasma treatment equipment is used abundantly with detailed-izing of semiconductor devices, such as LSI. The homogeneity of the above-mentioned plasma treatment within a wafer side contributes greatly stability, a yield, etc. of a property of this semiconductor device. The homogeneity of this plasma treatment is secured by distributing the plasma over homogeneity on a wafer front face. Then, by keeping away the distance of the plasma production section of for example, plasma treatment equipment, and a substrate, the plasma is diffused and the device of making it homogeneity can be considered on a wafer front face.
[0003]
Recently, the microwave plasma treatment equipment which is stabilized also in the state of a high vacuum with a comparatively low pressure, and can excite the plasma attracts attention among plasma treatment equipment.
[0004]
About the plasma treatment using this microwave plasma treatment equipment, concretely, it direct-oxidizes, and a silicon front face is nitrided, and the case where the insulator layer of high quality is formed is explained as an example.
[0005]
When using microwave plasma treatment equipment, the above-mentioned insulator layer is formed within a metal plasma treatment container. In order to form opening in the head-lining section of this plasma treatment container and to introduce microwave in equipment, the dielectric window for microwave transparency which is made of the quartz etc. is airtightly prepared in this opening.
[0006]
On the occasion of formation of the above-mentioned insulator layer, if the distance of the front face by the side of the substrate of this dielectric window and a substrate is about 80mm or less, an antenna may adjust the exposure reinforcement of microwave so that the plasma generated may become homogeneity according to the type of gas and pressure which are used for the plasma treatment concerned.
[0007]
By the plasma being high-density at a part for a center section, or detaching the distance between the front face of a dielectric window, and a substrate 80mm or more, even if it is the case that homogeneity — a ring-like high density part is formed on the other hand — is bad, the plasma is spread and homogeneity is secured on a substrate front face.
[0008]
By the way, when the plasma is excited with microwave plasma treatment equipment, the wave of the microwave called a surface wave between the front face of a dielectric window and the generated plasma is formed. As for this surface wave, the plasma is formed in the dielectric window whole surface in breadth and the substrate upper part.
[0009]
Usually, since the location of the internal surface of the head-lining section of a plasma

treatment container projects from the location of the front face of the above-mentioned dielectric window in the substrate side, the perimeter of this dielectric window is surrounded by the cross section of opening formed in the above-mentioned head-lining section. Therefore, if it reflects in the envelopment side where the above-mentioned surface wave consists of this opening cross section, a surface wave and this reflected wave will interfere mutually, and a standing wave will be formed near the front face of a dielectric window.

[0010]

This standing wave is the cause which checks the homogeneity of the plasma on the substrate front face in microwave plasma treatment. That is, the problem that the plasma consistency of the center section of the dielectric window turned into high density from the periphery of a dielectric window had arisen.

[0011]

Then, the configuration of an equipment wall surface where the periphery section of a dielectric window and a dielectric window are installed is made unevenness, and he negates a reflected wave, and was trying for a standing wave not to arise conventionally (for example, patent reference 1 reference.).

[0012]

[Patent reference 1]

JP,2002-190449,A (claim)

[0013]

[Translation done.]

EFFECT OF THE INVENTION

[Effect of the Invention]
In the plasma treatment for which this invention used microwave so that clearly from the above explanation Or it constitutes so that it may be located in a substrate side rather than this head-lining section internal surface. the front face of the dielectric window which countered the substrate — the same location as the location of the head-lining section internal surface of a plasma treatment container — with the periphery section of a dielectric window further By detaching the distance between the side-attachment-wall sides of a plasma treatment container more than the quadrant of the wavelength of microwave, the standing wave which was the cause of reducing the homogeneity of the plasma until now can be controlled now. Therefore, even when the distance of the front face of a dielectric window and a substrate was near, even if it can secure the homogeneity of plasma treatment now and changed the type of gas and the pressure, it became possible to perform high processing of the homogeneity of the plasma, without adjusting the configuration of equipment each time.

[Translation done.]

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention]
However, after it made it correspond to the plasma treatment in a certain specific type of gas and specific pressure and the antenna adjusted the exposure reinforcement of microwave, when plasma treatment was performed by a different type of gas or a different pressure, there was inconvenience that the homogeneity of the plasma worsened.
[0014]
Therefore, since when performing plasma treatment by two or more different types of gas or pressures, respectively had to adjust the exposure reinforcement of microwave each time, two or more plasma treatment from which a type of gas or a pressure differs by adjustment once was not completed, but there was [a problem that working efficiency fell].
[0015]
On the other hand, although the homogeneity on the front face of a substrate was securable when the distance between the front face of a dielectric window and a substrate was detached, the plasma consistency on the front face of a substrate fell simultaneously, the amount of attainment to the substrate of a labile kind decreased, and the problem that plasma treatment took time amount had arisen.
[0016]
Furthermore, although the above-mentioned inconvenience was canceled when making unevenness the configuration of the side attachment wall side of a plasma treatment container where the periphery section of a dielectric window and a dielectric window were installed in order to make it not produce the standing wave of the cause which checks the homogeneity of the plasma on the front face of a substrate, the processing technique make into an uneven configuration is complicated, and had substantially the problem that processing was difficult.
[0017]
Even if this invention does not perform complicated processing to the above-mentioned dielectric window in view of the above-mentioned trouble, it is made not to produce a standing wave near the front face of a dielectric window, and it makes it a technical problem to offer the microwave plasma treatment equipment and the art which can secure the homogeneity of the plasma on the front face of a substrate.
[0018]

[Translation done.]

MEANS

[Means for Solving the Problem]
In order to solve the above-mentioned technical problem, the microwave plasma treatment equipment concerning this invention The head-lining section is equipped with the plasma treatment container by which opening was carried out, and the dielectric window for microwave transparency airtightly prepared in this head-lining section at least. In the microwave plasma treatment equipment constituted so that the above-mentioned dielectric window may be countered and a substrate can be installed in a plasma treatment container the location as the location of the head-lining section internal surface of a plasma treatment container where the front face of the above-mentioned dielectric window which countered the substrate is the same — or it is characterized by being constituted so that it may be projected and located in a substrate side rather than the location of this head-lining section internal surface.

[0019]
Since there is no envelopment side which becomes the periphery section of a dielectric window from the cross section of opening formed in the head-lining section of a plasma treatment container according to this configuration, a surface wave does not reflect but formation of a standing wave can be controlled.

[0020]
Therefore, even if it changes conditions, such as a type of gas and a pressure, regardless of the distance of a dielectric window front face and a substrate, uniform plasma distribution can be acquired on a substrate front face.

[0021]
When the front face of the above-mentioned dielectric window which countered the substrate is located in a substrate side from the head-lining section internal surface of a plasma treatment container, as for the distance from this head-lining section internal surface to the front face of a dielectric window, it is desirable that it is at least 5mm.

[0022]
the location as the location of the head-lining section internal surface of a plasma treatment container where the front face of the inside surrounded by this lobe is the same when a ring-like lobe is prepared in the outside edge of the front face of the above-mentioned dielectric window which countered the substrate — or what is necessary is just to constitute so that it may be projected and located in a substrate side rather than the location of this head-lining section internal surface

[0023]
In addition, as for the distance between the periphery section of the above-mentioned dielectric window, and the side-attachment-wall side of a plasma treatment container, it is desirable that it is separated more than the quadrant of the wavelength of the microwave to introduce. This is for suppressing that microwave reflects in the direction of a center section of a dielectric window, and forms a standing wave by giving the tooth space in which the plasma is made to form between the periphery section of a dielectric window, and the side-attachment-wall side of a plasma treatment container.

[0024]

What is necessary is just to set distance of the periphery section of the above-mentioned dielectric window, and the side-attachment-wall side of a plasma treatment container to 30mm or more, when the frequency of the microwave which follows, for example, is introduced is 2.45GHz.
[0025]
Moreover, as for the path of the above-mentioned dielectric window, it is desirable that it is twice [more than] the path of a substrate. What is necessary is to make into a radius distance of the inside front face and substrate which were surrounded by this lobe, and just to set the path of a dielectric window that this lobe is not contained in each circle centering on substrate both ends, when preparing the above-mentioned lobe in the periphery section of a dielectric window furthermore. The die length of the path of a desirable dielectric window differs for not affecting the thickness of a substrate edge by the lobe by the existence of this lobe.
[0026]
In order to solve the above-mentioned technical problem, moreover, the microwave plasma treatment approach concerning this invention The material gas for exciting the plasma with a gas supply means is supplied to a plasma treatment container. The microwave made to oscillate and amplify with a microwave generating means is made to introduce and irradiate an antenna means. This irradiated microwave is introduced into the above-mentioned plasma treatment container of a vacuum ambient atmosphere through the dielectric window for microwave transparency. In the art which carries out microwave plasma treatment of the substrate which generated the plasma, countered the above-mentioned dielectric window for microwave transparency, and was formed in the plasma treatment container by the electromagnetic field which this microwave builds It is characterized by performing plasma treatment to one of the above using the microwave plasma equipment of a publication.
[0027]
[Embodiment of the Invention]
Hereafter, the microwave plasma treatment equipment concerning the gestalt of operation of this invention is explained with reference to drawing 1 , drawing 2 , and drawing 3 .
[0028]
Drawing 1 is a sectional view showing the configuration of the microwave plasma treatment equipment for semi-conductor substrates as 1 operation gestalt of this invention. Drawing 3 and drawing 4 are the sectional views showing the conventional common microwave plasma treatment equipment for semi-conductor substrates.
[0029]
In drawing 1 , 1 is a metal plasma treatment container which performs plasma treatment. The coaxial waveguide converter and antenna 2 which adjust the exposure reinforcement of microwave are formed in the upper part of the head-lining section 101 of the plasma treatment container 1. The slot 3 which irradiates microwave is established between the coaxial waveguide converter and the antenna 2, and the dielectric window 4 airtightly prepared in opening of the head-lining section 101. In addition, the raw material of the above-mentioned dielectric window 4 is a quartz etc. This dielectric window 4 penetrates the microwave irradiated through the slot 3, and introduces microwave in the plasma treatment container 1.
[0030]
It oscillates by the magnetron 5 and this microwave (2.45GHz) is introduced into the above-mentioned coaxial waveguide converter and an antenna 2 through a waveguide 8.
[0031]
Inside the plasma treatment container 1, the above-mentioned derivative aperture 4 and the electrode 13 which holds the plasma treatment substrate 12 in the location which counters are, and a RF is impressed to this electrode 13 in it if needed from RF generator 14. In addition, the adjustment machine 15 performs impedance adjustment of this RF.
[0032]
Next, actuation of the microwave plasma treatment equipment in this operation gestalt is explained. From the side face of the plasma treatment container 1, the gas for exciting the plasma with the gas supply means 9 is supplied, the inside of the plasma treatment container 1 is

made reduced pressure with a flue system 10, a pressure regulating valve 11 adjusts the process pressure of the plasma treatment container 1, and a raw material and reaction secondary generation gas are exhausted. The microwave oscillated and amplified by the magnetron 5 is introduced into a coaxial waveguide converter and an antenna 2 through the 4E tuner 7, and is irradiated from a slot 3. At this time, although a reflected wave is returned to the microwave processing container 1 side by the 4E tuner 7, it has prevented being absorbed with an isolator 6 about the reflected wave which cannot be adjusted, and returning to a magnetron 5. The microwave irradiated from the slot 3 is introduced inside the plasma treatment container 1 of a vacuum ambient atmosphere through a dielectric window 4, and forms Plasma P in the plasma treatment container 1 by the electromagnetic field which this microwave builds. This plasma P can perform etching, a membrane formation process, etc. In addition, SWP expresses typically the front face of the derivative aperture 4, and the surface wave of the microwave produced between Plasma P.

[0033]
When performing oxidation treatment using the above-mentioned microwave plasma treatment equipment, rare gas and oxygen, such as an argon and a krypton, are mixed, more than total 0.17 Pa-m3/sec (100sccm) is introduced, and it processes in a 1-133Pa pressure range. the case where nitriding treatment is performed on the other hand — for example, an argon, a krypton, etc. — etc. — rare gas, ammonia, nitrogen, and hydrogen are mixed, more than total 0.17 Pa-m3/sec (100sccm) is introduced, and it processes in a 1-133Pa pressure range.

[0034]
In drawing 1 , the location of the front face of the dielectric window 4 of the side which counters a substrate 12 projects in the substrate 12 side rather than the location of the internal surface of the head-lining section 101 of the microwave processing container 1. Therefore, that a surface wave SWP is irradiated by the metal side of the side attachment wall of the plasma treatment container 1 also forms an antinode and a knot in the periphery section of a dielectric window 4, without being reflected from a metal side. In addition, when it projects in a substrate 12 side and makes the front face of a dielectric window 4 located, the distance from the front face of a dielectric window 4 to the internal surface of the above-mentioned head-lining section 101 has about 5mm more desirable than the location of the internal surface of the above-mentioned head-lining section 101.

[0035]
In addition, what is necessary is to make into a radius r distance of the inside front face and substrate 12 which were surrounded by this lobe, and just to set the path of a dielectric window 4 that this lobe is not contained in each circle c centering on the both ends of a substrate 12 as drawing 2 shows when preparing a lobe in the periphery section of a dielectric window 4 like drawing 1 although it is desirable that it is twice [more than] the path of a substrate 12 as for the path of a dielectric window 4. The die length of the path of the desirable dielectric window 4 differs for not affecting the thickness of the edge of a substrate 4 by the lobe by the existence of this lobe. For example, the distance of the inside front face and substrate 12 which were surrounded by the lobe in drawing 1 is about 60mm, and when a substrate 4 is 200mm, the path of the inside surrounded by the lobe of a dielectric window 4 is set to about 280mm.

[0036]
Although the wave-like plasma may be formed depending on a pressure between the periphery section of a dielectric window 4, and the side-attachment-wall side of the plasma treatment container 1 at this time, in view of a substrate 12 side, this does not influence the plasma treatment of the front face of a substrate 12, but in order to consume power in the above-mentioned periphery section conversely, the plasma P of the front face of the dielectric window 4 on a substrate 12 becomes homogeneity. In this case, what is necessary is just to detach the distance between the periphery section of a dielectric window 4, and the side-attachment-wall side of the plasma treatment container 1 more than the quadrant of the wavelength of the microwave to introduce. For example, with the gestalt of this operation, since the microwave to introduce is 2.45GHz, it should just detach the distance of about 30mm or more so much in wavelength of 122mm.

[0037]
Although the coaxial waveguide converter and antenna 2 which are irradiated through a slot 3 are used as a means to introduce microwave in the microwave processing container 1, with the gestalt of this operation after changing microwave into the same axle, as an antenna means, otherwise, especially the thing that put in the slit can especially be used for a waveguide 8, and it is not limited to it.
[0038]
Drawing 3 shown for a comparison and the microwave plasma treatment equipment of a fundamental configuration of drawing 4 are the same as that of drawing 1 , and the same sign as drawing 1 shows the same configuration about the sign in drawing. In addition, the difference between the equipment of drawing 3 and the equipment of drawing 4 is the point that this lobe is not prepared in the outside edge of the front face of a dielectric window 4 by drawing 3 to having prepared the ring-like lobe, in drawing 4 . Since drawing 3 and drawing 4 are in the location from a substrate 12 side where the location of the front face of a dielectric window 4 is more distant than the location of the internal surface of the head-lining section 101 in any case, the metal envelopment side which consists of an opening cross section formed in this head-lining section 101 is formed in the perimeter of a dielectric window 4. Although SWP' and SWP" are the surface waves expressed typically, since they short-circuit all in respect of [above-mentioned] metal envelopment, they generate a standing wave strong against a part for a center section. Consequently, a plasma consistency also becomes high in the part of the shape of a ring which encloses the center of a dielectric window 4, and the center of a dielectric window 4, and will spoil homogeneity.
[0039]

[Translation done.]

EXAMPLE

[Example]
The example of the plasma treatment hereafter performed using the microwave plasma treatment equipment concerning this invention is explained as compared with the case of conventional microwave plasma treatment equipment.
[0040]
Plasma oxidation processing and plasma nitriding treatment of the substrate 12 from which the natural oxidation film was removed were carried out to drawing 1 by rare 0.5% fluoric acid using the microwave plasma treatment equipment of drawing 3 , respectively.
[0041]
Plasma oxidation performed 80Pa and the processing time for the pressure as 10 minutes using Kr/O2 gas. On the other hand, plasma nitriding performed 8Pa and the processing time for the pressure as 7 minutes using Ar/NH3 gas. In the equipment of drawing 1 and drawing 3 , the distance of the front face of a dielectric window 4 and a substrate 12 was adjusted, and both were set to 60mm.
[0042]
thickness distribution of the oxide film in the location of the arbitration after plasma treatment and on a substrate and the nitride film — a spectrum — it measured by the distributed ellipsometer and the result was compared. The result of oxidation treatment is shown in drawing 5 , and the result of nitriding treatment is shown in drawing 6 , respectively.
[0043]
When plasma treatment is carried out using the microwave plasma treatment equipment concerning this invention, thickness distribution all shows good homogeneity. That is, each thickness is fixed near about 71A - 72A, when it oxidizes (drawing 5), and when nitriding treatment is carried out, it is fixed near about 46A - 50A (drawing 6). In addition, although not illustrated, also in different oxidation treatment and the nitriding treatment of conditions from the above, it was the same distribution inclination.
[0044]
On the other hand, when plasma treatment is carried out using the microwave plasma treatment equipment of drawing 3 , it turns out that the thickness of a substrate center section is all thick. That is, although it is about 80A in a substrate periphery when it oxidizes, it is about 103A in the substrate center section (drawing 5), and although it is about 33A in a substrate periphery when nitriding treatment of each thickness is carried out, it is about 59A in the substrate center section (drawing 6). The microwave reflected in respect of the envelopment of the above-mentioned metal which consists of an opening cross section formed in the head-lining section 101 forms a standing wave, and this is considered for the plasma consistency of the substrate center section of the dielectric window 4 to have gone up, as SWP' of drawing 3 showed.
[0045]
Furthermore, when it was 80Pa with a comparatively high pressure, the wave-like plasma was formed between the periphery section of the dielectric window 4 of the microwave plasma treatment equipment of drawing 1 , and the side-attachment-wall side of the plasma treatment container 1. Since this detached the distance between the periphery section of a dielectric

window 4, and the side-attachment-wall side of the plasma treatment container 1 more than the quadrant of the wavelength of the microwave to introduce With the conventional microwave plasma treatment equipment of drawing 3 To microwave reflecting in the center section of the dielectric window 4, in the case of the equipment of drawing 1 , the plasma is formed between the periphery section of a dielectric window 4, and the side-attachment-wall side of the plasma treatment container 1, and it thinks because it has prevented microwave reflecting in the center section of the dielectric window 4.
[0046]

[Translation done.]

* NOTICES *

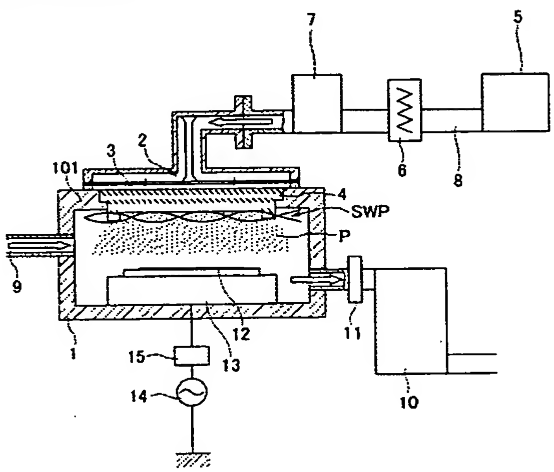
DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] The sectional view of the microwave plasma treatment equipment concerning this invention.
[Drawing 2] The sectional view showing the method of the decision of the path of the dielectric window at the time of preparing a lobe
[Drawing 3] The sectional view of conventional microwave plasma treatment equipment.
[Drawing 4] The sectional view of conventional microwave plasma treatment equipment (what prepared the ring-like lobe in the outside edge of the front face of a dielectric window).
[Drawing 5] Drawing showing the thickness distribution at the time of carrying out plasma oxidation processing of the silicon substrate using the equipment of drawing 1 and drawing 3
[Drawing 6] Drawing showing the thickness distribution at the time of carrying out plasma nitriding treatment of the silicon substrate to drawing 1 using the equipment of drawing 3
[Description of Notations]
1 Plasma Treatment Container
2 Coaxial Waveguide Converter and Antenna
3 Slot
4 Dielectric Window
5 Magnetron
6 Isolator
7 4E Tuner
8 Waveguide
9 Gas Supply Means
10 Exhaust Air Pump
11 Pressure Regulating Valve
12 Substrate
13 Electrode
14 RF Generator
15 Adjustment Machine
P Plasma
SWP surface wave

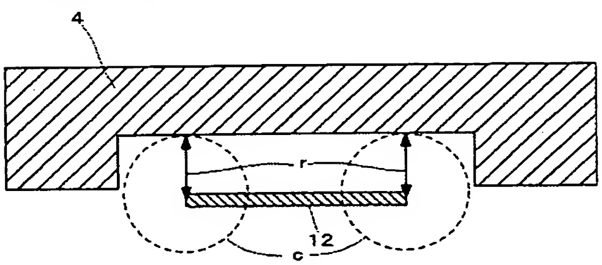
[Translation done.]

DRAWINGS

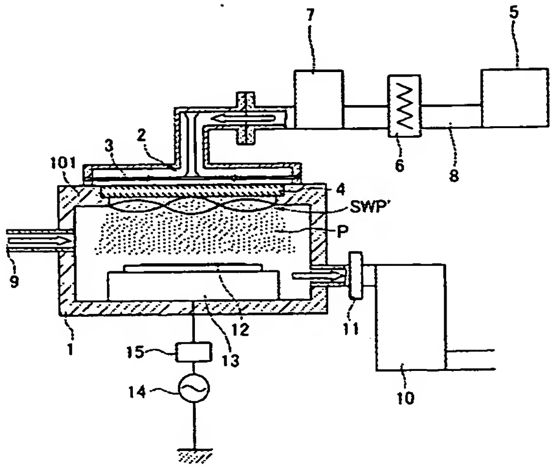
[Drawing 1]



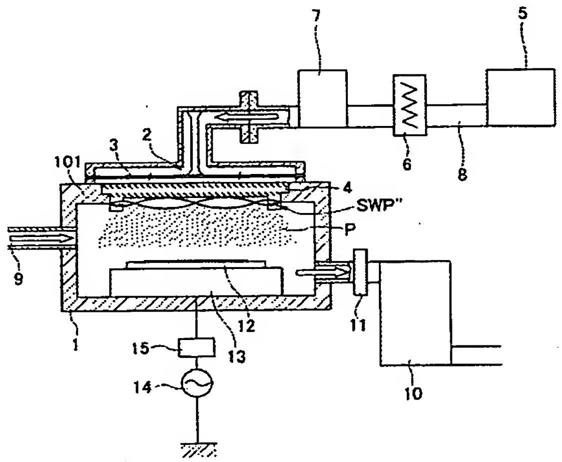
[Drawing 2]



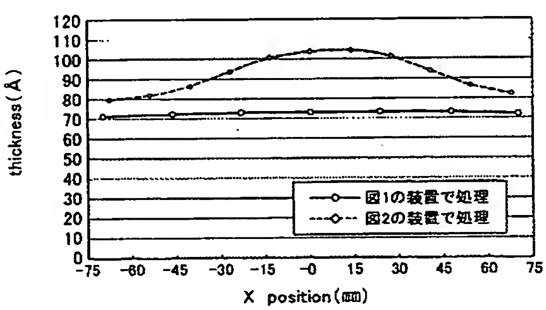
[Drawing 3]



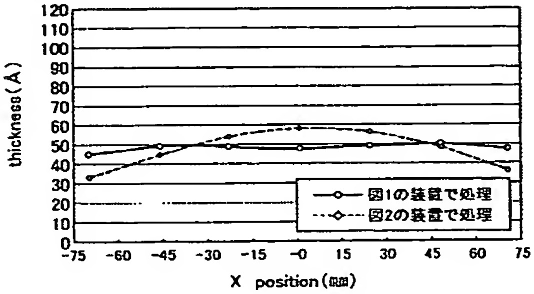
[Drawing 4]



[Drawing 5]



[Drawing 6]



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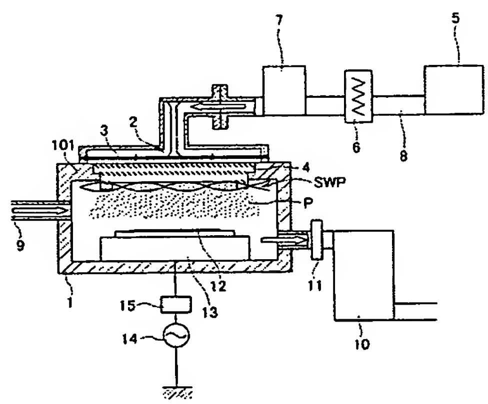
(54)【発明の名称】マイクロ波プラズマ処理装置および処理方法

(57)【要約】
【課題】誘電体窓に複雑な加工を施さなくても、誘電体窓の表面付近で定在波を生じさせないようにし、基板表面のプラズマの均一性を確保できるマイクロ波プラズマ処理装置および処理方法を提供することを課題とする。
【解決手段】マイクロ波透過用誘電体窓の基板に対向した上記誘電体窓の表面が、プラズマ処理容器の天井部内壁面の位置と同じ位置かもしくはこの天井部内壁面の位置よりも基板側に突出して位置するように構成し、さらにマイクロ波透過用誘電体窓の外周部とプラズマ処理容器の側壁面との距離を導入するマイクロ波の波長の少なくとも４分の１以上にすることにより、誘電体窓に複雑な加工を施さなくても基板表面のプラズマの均一性を確保することが可能になった。
【選択図】 図１



【特許請求の範囲】
【請求項１】
天井部が開口されたプラズマ処理容器と、この天井部に気密に設けられたマイクロ波透過用誘電体窓とを少なくとも備え、上記誘電体窓に対向してプラズマ処理容器内に基板が設置できるように構成されているマイクロ波プラズマ処理装置において、基板に対向した上記誘電体窓の表面が、プラズマ処理容器の天井部内壁面の位置と同じ位置かもしくはこの天井部内壁面の位置よりも基板側に突出して位置するように構成されていることを特徴とするマイクロ波プラズマ処理装置。
【請求項２】
基板に対向した上記誘電体窓の表面が、プラズマ処理容器の天井部内壁面の位置から少なくとも５ｍｍ基板側に突出して位置するように構成されていることを特徴とする請求項１記載のマイクロ波プラズマ処理装置。
【請求項３】
基板に対向した上記誘電体窓の表面の外側縁部にリング状の突出部を設けた場合に、この突出部に囲まれた内側の表面が、プラズマ処理容器の天井部内壁面の位置と同じ位置かもしくはこの天井部内壁面の位置よりも基板側に突出して位置するように構成されていることを特徴とする請求項１もしくは請求項２記載のマイクロ波プラズマ処理装置。
【請求項４】
上記誘電体窓の外周部とプラズマ処理容器の側壁面との間の距離が、導入するマイクロ波の波長の４分の１以上離れていることを特徴とする請求項１記載乃至請求項３のいずれかに記載のマイクロ波プラズマ処理装置。
【請求項５】
導入するマイクロ波の周波数が２．４５ＧＨｚの場合に、上記誘電体窓の外周部とプラズマ処理容器の側壁面との間の距離が３０ｍｍ以上であることを特徴とする請求項４記載のマイクロ波プラズマ処理装置。
【請求項６】
上記誘電体窓の径が、基板の径の２倍以上であることを特徴とする請求項１乃至請求項５のいずれかに記載のマイクロ波プラズマ処理装置。
【請求項７】
誘電体窓が請求項３記載の突出部を設けたものである場合は、この突出部に囲まれた内側の表面と基板との距離を半径とし、基板両端部を中心とするそれぞれの円内にこの突出部が含まれないように誘電体窓の径を定めたことを特徴とする請求項２乃至請求項５のいずれかに記載のマイクロ波プラズマ処理装置。
【請求項８】
ガス供給手段によってプラズマを励起するための原料ガスをプラズマ処理容器に供給し、マイクロ波発生手段により発振、増幅せしめたマイクロ波をアンテナ手段に導入して照射させ、この照射されたマイクロ波をマイクロ波透過用誘電体窓を介して真空雰囲気の上記プラズマ処理容器に導入し、このマイクロ波のつくる電磁界によってプラズマ処理容器内にプラズマを生成し、上記マイクロ波透過用誘電体窓に対向して設けられた基板をマイクロ波プラズマ処理する処理方法において、請求項１乃至請求項７のいずれかに記載のマイクロ波プラズマ装置を用いてプラズマ処理を行うことを特徴とするマイクロ波プラズマ処理方法。
【発明の詳細な説明】
【０００１】
【発明の属する技術分野】
本発明は、マイクロ波プラズマ処理装置およびこの装置を用いた処理方法に関する。
【０００２】
【従来の技術】
近年、ＬＳＩなどの半導体デバイスの微細化にともない、半導体デバイスの製造工程においてプラズマ処理装置が多用されている。この半導体デバイスの特性の安定や歩留まりな

どは、ウェハ面内における上記プラズマ処理の均一性が大きく寄与する。このプラズマ処理の均一性は、プラズマをウェハ表面で均一に分布させることによって確保される。そこで、たとえばプラズマ処理装置のプラズマ生成部と基板との距離を遠ざけることによってプラズマを拡散させてウェハ表面では均一にするなどの工夫が考えられる。
【０００３】
プラズマ処理装置のうち、最近では、比較的圧力の低い高真空状態でも安定してプラズマを励起することができるマイクロ波プラズマ処理装置が注目されている。
【０００４】
このマイクロ波プラズマ処理装置を用いたプラズマ処理について、具体的にシリコン表面を直接酸化および窒化し、高品質の絶縁膜を形成する場合を例として説明する。
【０００５】
マイクロ波プラズマ処理装置を用いる場合、金属製のプラズマ処理容器内で上記絶縁膜を形成する。このプラズマ処理容器の天井部には開口部が形成され、マイクロ波を装置内に導入するために、石英などからできているマイクロ波透過用誘電体窓がこの開口部に気密に設けられている。
【０００６】
上記絶縁膜の形成に際し、この誘電体窓の基板側の表面と基板との距離がおよそ８０ｍｍ以下であれば、当該プラズマ処理に使用されるガス種や圧力に応じ、生成されるプラズマが均一になるように、マイクロ波の照射強度をアンテナで調整することがある。
【０００７】
一方、プラズマが中央部分で高密度であったり、あるいはリング状の高密度部分が形成されるなど均一性が悪い場合であっても、誘電体窓の表面と基板との間の距離を８０ｍｍ以上離すことによってプラズマが拡散され、基板表面では均一性が確保される。
【０００８】
ところで、マイクロ波プラズマ処理装置でプラズマを励起した場合、誘電体窓の表面と発生したプラズマとの間で表面波と呼ばれるマイクロ波の波が形成される。この表面波は誘電体窓一面に広がり、基板上方ではプラズマが形成される。
【０００９】
通常、プラズマ処理容器の天井部の内壁面の位置は、上記誘電体窓の表面の位置よりも基板側に突起しているため、この誘電体窓の周囲は、上記天井部に形成された開口部の断面によって包囲されている。従って上記表面波がこの開口部断面からなる包囲面に反射すると、表面波とこの反射波が互いに干渉して誘電体窓の表面近傍で定在波が形成される。
【００１０】
この定在波が、マイクロ波プラズマ処理における基板表面上のプラズマの均一性を阻害する原因になっている。すなわち、誘電体窓の中央部のプラズマ密度が誘電体窓の周辺部よりも高密度になるという問題が生じていた。
【００１１】
そこで、従来、誘電体窓の外周部および誘電体窓が設置されている装置壁面の形状を凸凹にして反射波を打ち消し、定在波が生じないようにしていた（例えば、特許文献１参照。）。
【００１２】
【特許文献１】
特開平２００２－１９０４４９号（特許請求の範囲）
【００１３】
【発明が解決しようとする課題】
しかしながら、ある特定のガス種および圧力におけるプラズマ処理に対応させて、アンテナでマイクロ波の照射強度を調整した後、異なるガス種もしくは圧力でプラズマ処理を行うと、プラズマの均一性が悪くなるという不都合があった。
【００１４】
従って、複数の異なるガス種もしくは圧力でそれぞれプラズマ処理を行う場合は、マイク

ロ波の照射強度をその都度調整しなければならないため、一度の調整でガス種もしくは圧力が異なる複数のプラズマ処理はできず、作業効率が低下するという問題があった。

【００１５】

一方、誘電体窓の表面と基板との間の距離を離すと、基板表面での均一性は確保できるが、同時に基板表面でのプラズマ密度が下がり、反応活性種の基板への到達量が減少し、プラズマ処理に時間がかかるという問題が生じていた。

【００１６】

さらに、基板表面のプラズマの均一性を阻害する原因の定在波を生じさせないようにするために、誘電体窓の外周部および誘電体窓が設置されているプラズマ処理容器の側壁面の形状を凸凹にすれば、上記不都合は解消されるが、凸凹の形状にする加工技術は複雑であり、実質的に加工が困難であるという問題があった。

【００１７】

本発明は、上記問題点に鑑み、上記誘電体窓に複雑な加工を施さなくても、誘電体窓の表面付近で定在波を生じさせないようにし、基板表面のプラズマの均一性を確保できるマイクロ波プラズマ処理装置および処理方法を提供することを課題とする。

【００１８】

【課題を解決するための手段】

上記課題を解決するため、本発明にかかるマイクロ波プラズマ処理装置は、天井部が開口されたプラズマ処理容器と、この天井部に気密に設けられたマイクロ波透過用誘電体窓とを少なくとも備え、上記誘電体窓に対向してプラズマ処理容器内に基板が設置できるように構成されているマイクロ波プラズマ処理装置において、基板に対向した上記誘電体窓の表面が、プラズマ処理容器の天井部内壁面の位置と同じ位置かもしくはこの天井部内壁面の位置よりも基板側に突出して位置するように構成されていることを特徴とする。

【００１９】

この構成によれば、誘電体窓の外周部には、プラズマ処理容器の天井部に形成された開口部の断面からなる包囲面がないため、表面波が反射せず、定在波の形成を抑制することができる。

【００２０】

従って、誘電体窓表面と基板との距離に関係なく、また、ガス種や圧力などの条件を変化させても、基板表面で均一なプラズマ分布を得ることができる。

【００２１】

基板に対向した上記誘電体窓の表面が、プラズマ処理容器の天井部内壁面より基板側に位置する場合、この天井部内壁面から誘電体窓の表面までの距離は少なくとも５ｍｍであることが望ましい。

【００２２】

基板に対向した上記誘電体窓の表面の外側縁部に、リング状の突出部を設けた場合は、この突出部に囲まれた内側の表面が、プラズマ処理容器の天井部内壁面の位置と同じ位置かもしくはこの天井部内壁面の位置よりも基板側に突出して位置するように構成すればよい。

【００２３】

なお、上記誘電体窓の外周部とプラズマ処理容器の側壁面との間の距離は、導入するマイクロ波の波長の４分の１以上離れていることが好ましい。これは、誘電体窓の外周部とプラズマ処理容器の側壁面との間でプラズマを形成させるスペースを与えることによって、マイクロ波が誘電体窓の中央部方向に反射し、定在波を形成することを抑えるためである。

【００２４】

従って、例えば、導入するマイクロ波の周波数が２．４５ＧＨｚの場合に、上記誘電体窓の外周部とプラズマ処理容器の側壁面との距離は３０ｍｍ以上とすればよい。

【００２５】

また、上記誘電体窓の径は、基板の径の２倍以上であることが好ましい。さらに誘電体窓

の外周部に上記突出部を設けたものである場合は、この突出部に囲まれた内側の表面と基板との距離を半径とし、基板両端部を中心とするそれぞれの円内にこの突出部が含まれないように誘電体窓の径を定めればよい。この突出部の有無で好ましい誘電体窓の径の長さが異なるのは、突出部によって基板端部の膜厚に影響を与えないようにするためである。

【００２６】

また、上記課題を解決するため、本発明にかかるマイクロ波プラズマ処理方法は、ガス供給手段によってプラズマを励起するための原料ガスをプラズマ処理容器に供給し、マイクロ波発生手段により発振、増幅せしめたマイクロ波をアンテナ手段に導入して照射させ、この照射されたマイクロ波をマイクロ波透過用誘電体窓を介して真空雰囲気の上記プラズマ処理容器に導入し、このマイクロ波のつくる電磁界によってプラズマ処理容器内にプラズマを生成し、上記マイクロ波透過用誘電体窓に対向して設けられた基板をマイクロ波プラズマ処理する処理方法において、上記いずれかに記載のマイクロ波プラズマ装置を用いてプラズマ処理を行うことを特徴とする。

【００２７】

【発明の実施の形態】

以下、本発明の実施の形態にかかるマイクロ波プラズマ処理装置を図１、図２および図３を参照して説明する。

【００２８】

図１は、本発明の一実施形態として、半導体基板用のマイクロ波プラズマ処理装置の構成を表した断面図である。図３および図４は、従来の一般的な半導体基板用のマイクロ波プラズマ処理装置を表した断面図である。

【００２９】

図１において、１は、プラズマ処理を行う金属製のプラズマ処理容器である。プラズマ処理容器１の天井部１０１の上部には、マイクロ波の照射強度を調整する同軸導波変換器及びアンテナ２が設けられている。同軸導波変換器及びアンテナ２と、天井部１０１の開口部に気密に設けられた誘電体窓４との間には、マイクロ波を照射するスロット３が設けられている。なお、上記誘電体窓４の原材料は、石英などである。この誘電体窓４は、スロット３を介して照射されたマイクロ波を透過し、プラズマ処理容器１内にマイクロ波を導入する。

【００３０】

このマイクロ波（２．４５ＧＨｚ）は、マグネトロン５で発振し、導波管８を介して上記同軸導波変換器及びアンテナ２に導入される。

【００３１】

プラズマ処理容器１の内部には、上記誘導体窓４と対向する位置に、プラズマ処理基板１２を保持する電極１３があり、この電極１３に高周波電源１４から必要に応じて高周波を印加する。なお、この高周波のインピーダンス調整は整合器１５によって行う。

【００３２】

次に、本実施形態におけるマイクロ波プラズマ処理装置の動作を説明する。プラズマ処理容器１の側面から、ガス供給手段９によってプラズマを励起させるためのガスを供給し、排気システム１０によってプラズマ処理容器１内を減圧にし、プラズマ処理容器１のプロセス圧力を圧力調整弁１１によって調整し、原料および反応副生成ガスを排気する。マグネトロン５で発振、増幅されたマイクロ波は、４Ｅチューナ７を通して同軸導波変換器及びアンテナ２に導入され、スロット３から照射される。このとき反射波は、４Ｅチューナ７によってマイクロ波処理容器１側へ戻されるが、調整しきれない反射波についてはアイソレータ６で吸収されてマグネトロン５へ戻ることを防いでいる。スロット３から照射されたマイクロ波は、誘電体窓４を介して真空雰囲気のプラズマ処理容器１の内部へ導入され、このマイクロ波のつくる電磁界によってプラズマ処理容器１内にプラズマＰを形成する。このプラズマＰにより、エッチングや成膜プロセスなどを行うことができる。なお、ＳＷＰは、誘導体窓４の表面とプラズマＰとの間に生じるマイクロ波の表面波を模式的に表したものである。

【００３３】
上記マイクロ波プラズマ処理装置を用いて酸化処理を行う場合は、例えばアルゴンやクリプトンなどの希ガスと酸素を混合してトータル０．１７Ｐａ・ｍ^3／ｓｅｃ（１００ｓｃｃｍ）以上を導入し、１～１３３Ｐａの圧力範囲において処理する。一方、窒化処理を行う場合は、例えばアルゴンやクリプトンなどのなどの希ガスとアンモニア、窒素および水素を混合し、トータル０．１７Ｐａ・ｍ^3／ｓｅｃ（１００ｓｃｃｍ）以上を導入し、１～１３３Ｐａの圧力範囲において処理する。
【００３４】
図１において、基板１２に対向する側の誘電体窓４の表面の位置は、マイクロ波処理容器１の天井部１０１の内壁面の位置よりも基板１２側に突出している。従って、表面波ＳＷＰは、プラズマ処理容器１の側壁の金属面に照射されることも、金属面から反射されることもなく、誘電体窓４の外周部で腹と節を形成する。なお、上記天井部１０１の内壁面の位置よりも、誘電体窓４の表面を基板１２側に突出して位置するようにする場合には、誘電体窓４の表面から上記天井部１０１の内壁面までの距離は５ｍｍ程度が好ましい。
【００３５】
なお、誘電体窓４の径は、基板１２の径の２倍以上であることが好ましいが、図１のように誘電体窓４の外周部に突出部を設けたものである場合は、図２で示すとおり、この突出部に囲まれた内側の表面と基板１２との距離を半径ｒとし、基板１２の両端部を中心とするそれぞれの円ｃ内にこの突出部が含まれないように誘電体窓４の径を定めればよい。この突出部の有無で好ましい誘電体窓４の径の長さが異なるのは、突出部によって基板４の端部の膜厚に影響を与えないようにするためである。たとえば、図１において突出部に囲まれた内側の表面と基板１２との距離が６０ｍｍ程度であり、基板４が２００ｍｍの場合、誘電体窓４の突出部に囲まれた内側の径はおよそ２８０ｍｍとなる。
【００３６】
このとき圧力によっては、基板１２側からみると誘電体窓４の外周部とプラズマ処理容器１の側壁面との間に波状のプラズマを形成することがあるが、これは基板１２の表面のプラズマ処理には影響せず、逆に上記外周部で電力を消費するため基板１２上の誘電体窓４の表面のプラズマＰは均一になる。この場合、誘電体窓４の外周部とプラズマ処理容器１の側壁面との間の距離は、導入するマイクロ波の波長の４分の１以上離せばよい。たとえば、本実施の形態では、導入するマイクロ波は、２．４５ＧＨｚであるから、波長１２２ｍｍにたいして約３０ｍｍ以上の距離を離せばよいことになる。
【００３７】
本実施の形態では、マイクロ波をマイクロ波処理容器１内に導入する手段として、マイクロ波を同軸に変換した後、スロット３を介して照射する同軸導波変換器及びアンテナ２を使用しているが、アンテナ手段としては、他に導波管８にスリットをいれたものなどを特に使用することができ特に限定されるものではない。
【００３８】
比較のために示す図３および図４のマイクロ波プラズマ処理装置も基本的構成は図１と同じであり、図中の符号については図１と同じ符号は同じ構成を示す。なお、図３の装置と図４の装置の違いは、図４では誘電体窓４の表面の外側縁部にリング状の突出部を設けているのに対し、図３でこの突出部が設けられていない点である。図３および図４はいずれの場合も、誘電体窓４の表面の位置が、天井部１０１の内壁面の位置よりも基板１２側から遠い位置にあるため、誘電体窓４の周囲には、この天井部１０１に形成された開口部断面からなる金属製の包囲面が形成されている。ＳＷＰ’およびＳＷＰ’’は、模式的に表した表面波であるが、いずれも上記金属製の包囲面で短絡されるため、中央部分に強い定在波を生成する。その結果、プラズマ密度も誘電体窓４の中央や誘電体窓４の中央を取り囲むリング状の部分で高くなり、均一性を損なうことになる。
【００３９】
【実施例】
以下、本発明にかかるマイクロ波プラズマ処理装置を用いて行うプラズマ処理の実施例に

ついて従来のマイクロ波プラズマ処理装置の場合と比較して説明する。

【００４０】

図１と図３のマイクロ波プラズマ処理装置を用いて０．５％希フッ酸により、自然酸化膜を除去した基板１２をそれぞれプラズマ酸化処理およびプラズマ窒化処理した。

【００４１】

プラズマ酸化は、Ｋｒ／O_2ガスを用い、圧力を８０Ｐａ、処理時間を１０分として行った。一方、プラズマ窒化はＡｒ／NH_3ガスを用い、圧力を８Ｐａ、処理時間を７分として行った。図１と図３の装置において、誘電体窓４の表面と基板１２との距離を調整してどちらも６０ｍｍとした。

【００４２】

プラズマ処理後、基板上の任意の位置における酸化物膜および窒化物膜の膜厚分布を分光分散エリプソメータで測定し、結果を比較した。酸化処理の結果を図５に窒化処理の結果を図６にそれぞれ示す。

【００４３】

本発明に係るマイクロ波プラズマ処理装置を用いてプラズマ処理した場合は、いずれも膜厚分布は良い均一性を示している。すなわち、それぞれの膜厚は、酸化処理した場合は、およそ７１Å～７２Å付近で一定であり（図５）、窒化処理した場合は、およそ４６Å～５０Å付近で一定である（図６）。なお、図示しないが、上記と異なる条件の酸化処理および窒化処理においても同様の分布傾向であった。

【００４４】

一方、図３のマイクロ波プラズマ処理装置を用いてプラズマ処理した場合は、いずれも基板中央部の膜厚が厚くなっていることがわかる。すなわち、それぞれの膜厚は、酸化処理した場合は、基板周辺部ではおよそ８０Åであるが、基板中央部ではおよそ１０３Åであり（図５）、窒化処理した場合は、基板周辺部ではおよそ３３Åであるが、基板中央部ではおよそ５９Åである（図６）。これは、図３のＳＷＰ’で示したように、天井部１０１に形成された開口部断面からなる上記金属製の包囲面で反射したマイクロ波が定在波を形成し、誘電体窓４の基板中央部のプラズマ密度が上がってしまったためと考えられる。

【００４５】

さらに、圧力が比較的高い８０Ｐａの場合、図１のマイクロ波プラズマ処理装置の誘電体窓４の外周部とプラズマ処理容器１の側壁面との間に波状のプラズマが形成された。これは、誘電体窓４の外周部とプラズマ処理容器１の側壁面との間の距離を、導入するマイクロ波の波長の４分の１以上離したために、図３の従来のマイクロ波プラズマ処理装置では、マイクロ波が誘電体窓４の中央部に反射してくるのに対し、図１の装置の場合には、誘電体窓４の外周部とプラズマ処理容器１の側壁面との間でプラズマを形成し、マイクロ波が誘電体窓４の中央部に反射するのを防いでいるためと考えられる。

【００４６】

【発明の効果】

以上の説明から明らかなように、本発明は、マイクロ波を利用したプラズマ処理において、基板に対向した誘電体窓の表面をプラズマ処理容器の天井部内壁面の位置と同じ位置かもしくはこの天井部内壁面よりも基板側に位置するように構成し、さらに誘電体窓の外周部と、プラズマ処理容器の側壁面との間の距離をマイクロ波の波長の４分の１以上離すことによって、これまでプラズマの均一性を低下させる原因であった定在波を抑制できるようになった。従って、誘電体窓の表面と基板との距離が近い場合でもプラズマ処理の均一性を確保できるようになり、また、ガス種や圧力を変化させても、その都度装置の構成を調整せずにプラズマの均一性の高い処理を行うことが可能となった。

【図面の簡単な説明】

【図１】本発明にかかるマイクロ波プラズマ処理装置の断面図。

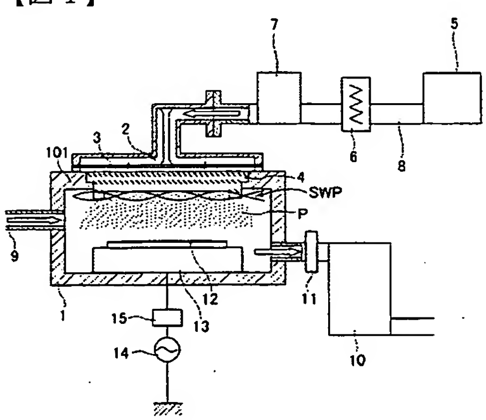
【図２】突出部を設けた場合の誘電体窓の径の決定の仕方を示す断面図

【図３】従来のマイクロ波プラズマ処理装置の断面図。

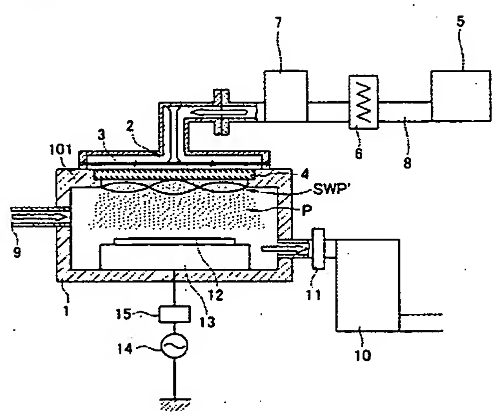
【図４】従来のマイクロ波プラズマ処理装置の断面図（誘電体窓の表面の外側縁部にリン

グ状の突出部を設けたもの）。
【図５】図１と図３の装置を使用してシリコン基板をプラズマ酸化処理した場合の膜厚分布を示す図
【図６】図１と図３の装置を使用してシリコン基板をプラズマ窒化処理した場合の膜厚分布を示す図
【符号の説明】
１　プラズマ処理容器
２　同軸導波変換器およびアンテナ
３　スロット
４　誘電体窓
５　マグネトロン
６　アイソレータ
７　４Ｅチューナ
８　導波管
９　ガス供給手段
１０　排気ポンプ
１１　圧力調整弁
１２　基板
１３　電極
１４　高周波電源
１５　整合器
Ｐ　プラズマ
ＳＷＰ表面波

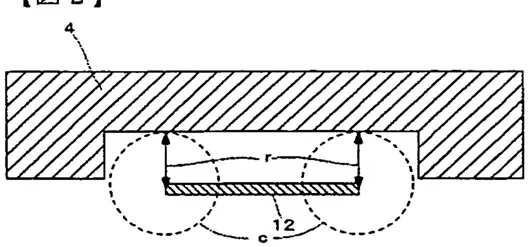
【図１】



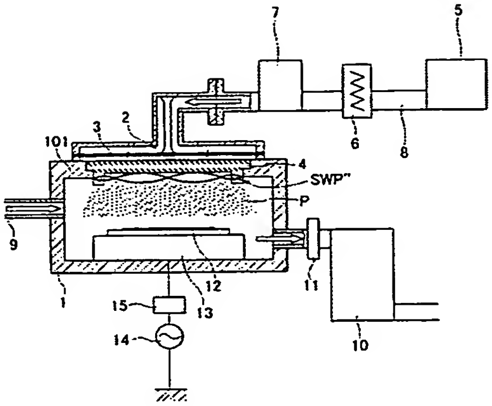
【図３】



【図２】



【図4】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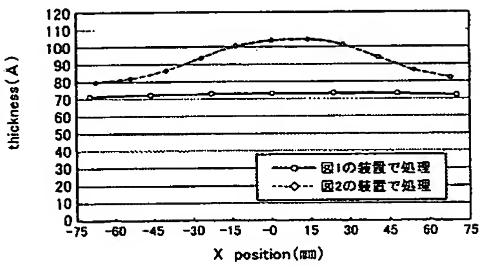
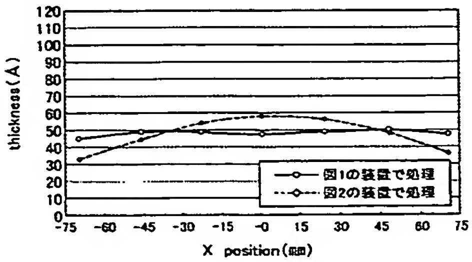
【図5】


thickness(A)
X position(mm)
図1の装置で処理
図2の装置で処理

【図6】


thickness(A)
X position(mm)
図1の装置で処理
図2の装置で処理

フロントページの続き

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DQ10 EH03